PATENT ABSTRACTS OF JAPAN

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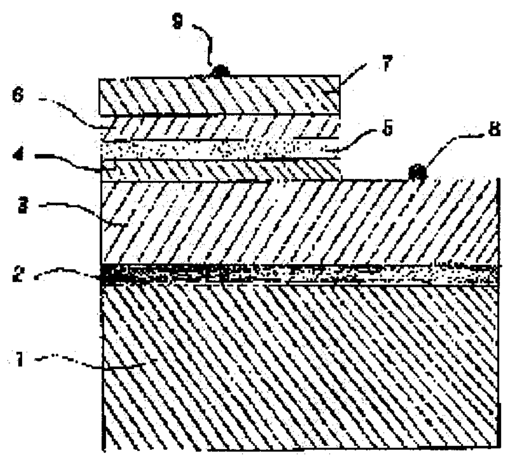
(54) NITRIDE SEMICONDUCTOR LIGHT EMITTING ELEMENT

(57)Abstract:

PROBLEM TO BE SOLVED: To improve the performance such as a light output characteristic and an electric characteristic of a light emitting element such as a visible light emitting diode, especially, a blue light emitting diode, by forming a p-type conductive layer implanted with a p-type dopant and an n-type dopant.

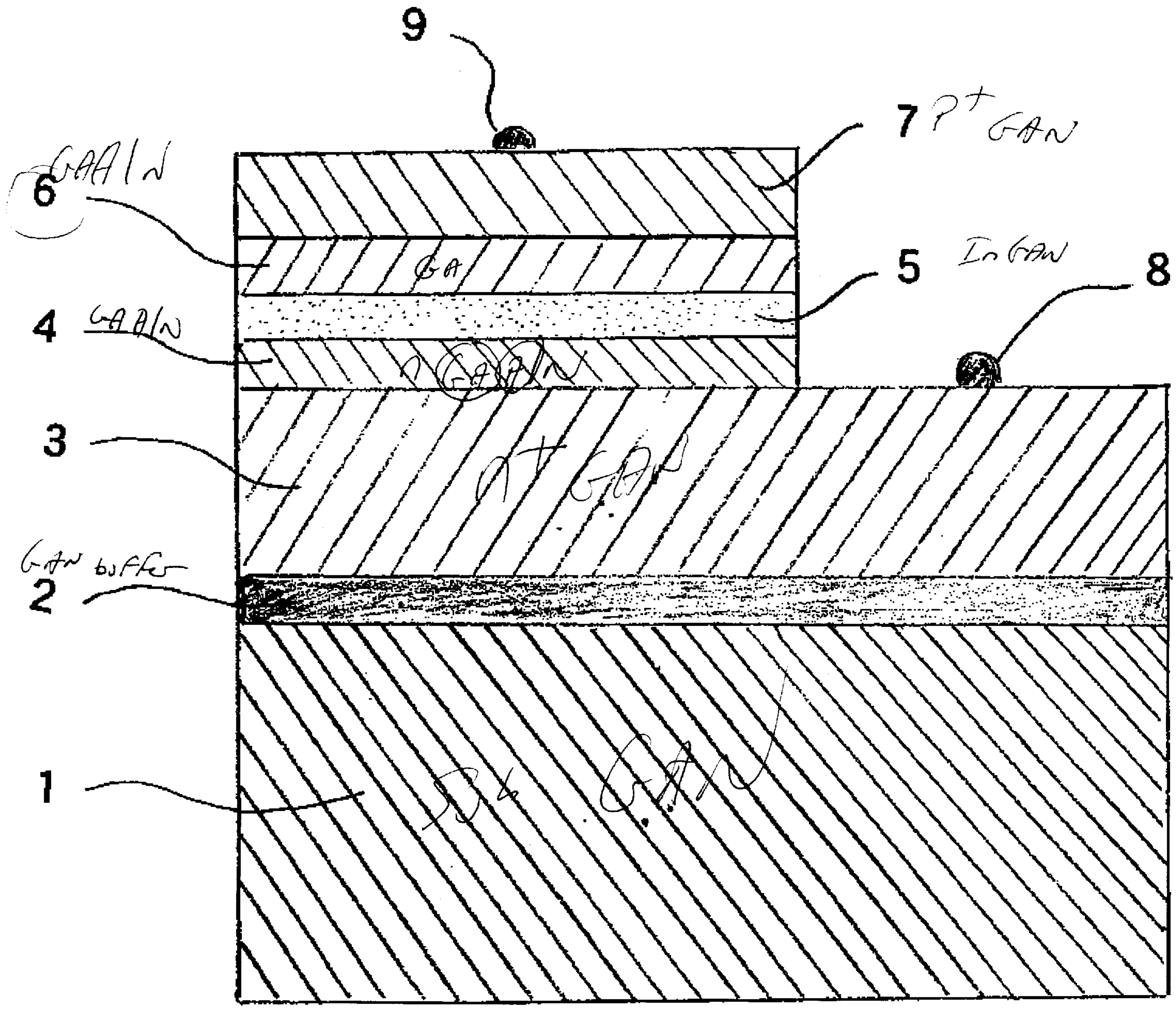
SOLUTION: Usually, sapphire is used for the material of a substrate 1. By a MOCVE method, a GaN buffer layer 2 is grown on the substrate 1 using hydrogen as a carrier gas and ammonia NH4 and trimethylgallium TMG as material gases, and then an n+ type GaN layer 3, an n-type GaAlN layer 4, an n-type InGaN layer 5, a p-type GaAlN layer 6, a p+ type GaN layer 7 are continuously grown as layers each having a carrier density and a thickness suitable for a light emitting element. The p-type conductive layers, that is, the p-type GaAlN layer 6 and the p+ type GaN layer 7, are formed into high density p-type conductive layers by a method related to the control of a carrier density. Accordingly, a semiconductor element including such layers can be increased in its performance.



[Document Name]Abstract

[Abstract]
[Technical problem] The luminescent property **** electrical property of the light emitting element ****(ed) from a nitride semiconductor is improved, and high-output operation and low-power-consumption operation are realized.
[Means for Solution]A light emitting element possessing a high growth layer of hole concentration formed by carrying out in donor type impurities and introducing with acceptor type impurities at the time of crystal growth as a means aiming at p type conductor layer formation in nitride semiconductors, such as GaN and InGaN, is provided.
[Chosen drawing] Drawing 1

[Translation done.]


9
7 P+ GAN
GAAlN
6
GA
5
InGAN
8
4
GAAlN
nGAN
3
N+ GAN
GAN buffer
2
1
P+ GAN

Notes:
1. Untranslatable words are replaced with asterisks (****).
2. Texts in the figures are not translated and shown as it is.

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Dictionary: Last updated 04/14/2009 / Priority:

[Document Name]Description

[Title of the Invention]Nitride semiconductor light emitting element

[Claim(s)]

[Claim 1]A nitride semiconductor element which having p type conduction layer containing p type dopant and n type dopant, and constituting.

[Claim 2]The nitride semiconductor light emitting element according to claim 1, wherein said p type conduction layer is a luminous layer or a cladding layer about a gallium nitride semiconductor layer containing a gallium nitride semiconductor layer and/or In containing aluminum.

[Claim 3]The nitride semiconductor light emitting element according to claim 2 having said p type conduction layer which consists of AlGaN(s) as a cladding layer further on a luminous layer which consists of InGaN(s).

[Claim 4]The nitride semiconductor element according to any one of claims 1 to 3 being said p type conduction layer which doped simultaneously and formed said p type dopant and n type

dopant so that it might become the abbreviation 3:1.

[Claim 5]The nitride semiconductor element according to any one of claims 1 to 4 constituted with p type conduction layer formed using VI fellows element as an n type dopant added simultaneously with p type dopant.

[Detailed Description of the Invention]

[0001]

[Field of the Invention]In this invention, especially high concentration hole concentration is obtained about the blue / light emitting element outside purple which used the nitride semiconductor.
Therefore, it is related with the light emitting element which has the outstanding luminescent property and electrical property.

[0002]

[Description of the Prior Art]Since nitride semiconductors, such as InGaN, GaN, AlGaN, and InAlGaN, are changes directly and it is the material which has that a band gap may be changed in 1.95-6.2 eV by composition control, and high heat stability, As a light emitting element, the expectation as a material of blue / light emitting diode outside purple, and a semiconductor laser is growing especially. Originally, in this nitride semiconductor material, since the low resistive layer turned into a high resistance layer is hard to be obtained even if it mainly doped p type impurities, luminous efficiency obstructed the utilization as a light emitting element small.

[0003]In a nitriding thing compound semiconductor, for example, a gallium nitride system compound semiconductor, if a crystal is grown up with vapor phase growth, the fact that

generally n type conduction layer is easy to be formed will be cited as this cause. Therefore, there is a problem that carrier concentration high enough is not obtained even if it dopes impurities used as an acceptor, such as Be, Mg, Ca, Zn, and Cd, as a dopant in order to form p type conduction layer. A crystal is put into around 1000 ** and a comparatively high growth temperature, moreover, if the nitrogen partial pressure of atmosphere is low to this main cause, dissociation of nitrogen will arise from a crystal to it, an empty lattice is formed in it at a nitrogen lattice point, and it is mentioned to it that this empty lattice acts as a donor. By growth conditions, although the quantity generated has a large change, it is said to be about $1x10^{17}/cm^3$-$1x10^{22}/cm^3$. Also by inventors' examination, in the usual growth conditions in MO-CVD method, the donor concentration resulting from a nitrogen sky lattice reaches -$4x10^{16}$ / cm^3 stand easily, and it especially also becomes 10^{18} / cm^3 stand by InN. Thus, in the gallium nitride system compound semiconductor at least, with size of the nitrogen partial pressure of growth source gas, composition of material, etc. in crystal growth, the difference was produced in the generation density of a nitrogen sky lattice, and generally, when nitrogen partial pressure was low, generation of a nitrogen sky lattice increased.

[0004]Although this donor should be compensated by the acceptor by addition of p type dopant, donor concentration should become small and acceptor concentration should become large soon, in fact, acceptor concentration reaches saturation to 10^{18} / cm^3 order, and decreases gradually after that. [the cause by which p type conduction layer with this high hole concentration is hard to be obtained] the original activation rate of the acceptor impurity of a under [a crystal] is not so large -- in addition, the hydrogen contained in growth source gas or conveyance gas combines with a crystal composition atom or impurities, a compound thing is formed, and it is mentioned that original activation of the impurities is barred. In order to realize p type conduction layer with high hole concentration, it is necessary to control so that neither these donors' formation nor formation of a compound thing may be proliferated, and to generate the acceptor concentration of a request.

[0005]The art of realizing the low resistance p type layer currently indicated by JP,H2-257679,A or JP,H5-183189,A was found out as a result of efforts to conquer such a technical problem. In the former, it has proposed that a low resistance p type layer is realizable with the art which carries out the annealing of the i type gallium nitride system compound semiconductor layer for the art which irradiates i type gallium nitride system compound semiconductor layer with an electron beam above 400 ** in the latter again. As a Reason a low

resistance p type layer is obtained by such art, when growing up a gallium nitride system compound semiconductor crystal with vapor phase growth, generally the compound which contains hydrogen or hydrogen as conveyance gas is used, using ammonia as a nitrogen source, but. In order that the hydrogen ionized at the time of a reaction here may combine with p type dopant doped by the gallium nitride system compound semiconductor, having barred the work on which p type dopant acts as an acceptor is indicated.

[0006]

[Problem to be solved by the invention]Although it has an effect remarkable for this art realizing formation of the gallium nitride system compound of low resistance, The rate activated as an acceptor to the total amount of p type dopant doped during a crystal by p type dopant concentration $10^{17}/cm^3$ About at most 4%, The hole carrier concentration which is about 0.1% and is obtained by $10^{19}/cm^3$ is $-5x10^{18}$ / cm^3 ****** at most. Since it becomes are the hole carrier concentration of after-growth 3 - $8x10^{17}/cm^3$, and insufficient [the usual growth conditions] forming of p-n junction, an ohmic nature electrode, etc., there is a problem from which sufficient element characteristic is not acquired. Formation of the activation prevention by the compound thing generated from combination with impurities and hydrogen as a Reason which is not mentioned in these hole carrier concentration 10 minutes as mentioned above, and the donor in a nitrogen sky lattice is mentioned.

[0007][the problem of the activation prevention by combination with this impurities and hydrogen] according to annealing processing, until solution can be carried out to some extent at least as it is known well that combination with hydrogen will go out by annealing processing in not less than 400-500 ** nitrogen shown in JP,H5-183189,A, and the function as an acceptor will be recovered. For example, although p type conduction layer is generally faced growing up and Mg which has the semi- grade of 160meV as the purpose of forming a shallower acceptor level is also is doped as impurities in GaN, AlGaN, and InGaN, Into crystal growth, if this AKUSEPU (Mg^+) meets with the proton (H^+) which entered into the crystal, it will join together electrically and it will form a Mg-H compound thing. solvable [by carrying out an annealing at the temperature of not less than 400 ** which a Mg-H compound thing decomposes after crystal growth] in JP,H5-183189,A -- the purport statement is carried out. However, in this technique, the decomposition removal of the Mg-H compound thing cannot fully be carried out,

but since Mg is not fully activated as an acceptor, an activation rate is also good and it is about 1%, and it has been a technical problem to low-resistance-izing. Element construction of the semiconductor laser etc. which need a high current potting machine style is still insufficient, and the further high concentration-ization is demanded.

[0008][therefore the target place / in view of a situation which was described above, accomplish this invention, and] It is a thing concerning the p-n junction accompanying realization of the high concentration p type conduction layer in a nitriding thing compound semiconductor, and formation of an ohmic electrode, It is in realizing improvement in performance of the optical power characteristic of light emitting elements, such as a visible light emitting diode and a visible semiconductor laser, which is mainly concerned with the blue built with those art, an electrical property, etc.

[0009]

[Means for solving problem]According to the invention of Claim 1, it has p type conduction layer containing p type dopant and n type dopant, and is constituted. Since p type conduction layer is formed easily, the performance of the semiconductor device constituted with this layer improves remarkably. In the light emitting diode, optimization of element structure was not measured but ** has also reduced the conventionally large driving power about 30 to 40%.

[0010]According to the invention of Claim 2, the layer which has the hole carrier concentration which is not in the former by applying the formation means of p type conduction layer to formation of a p type AlGaN layer or an InGaN layer is obtained, The light emitting element which was excellent in the semiconductor laser etc. which are equal to a light emitting diode with higher luminosity or high-output operation is realizable.

[0011]According to the invention of Claim 3, by the conventional method, in-series resistance was able to make easy construction of a semiconductor device which consists of ******** of an InGaN layer and an AlGaN layer which could not but become large. That is, compared with the conventional method, a high hole carrier concentration AlGaN layer has been formed at a low temperature.

[0012]According to Claim 4, suitable hole carrier concentration is covering a comparatively wide range to each semiconductor device, but a donor level and an acceptor level make a pair electrically, electrostatic energy is stable, and an acceptor atom becomes difficult to be displaced from a lattice point. Since an atom which acts on a symmetrical position as an acceptor further via a donor in this atomic pair is considered that composition arranged is stable, It can control by doping simultaneously the amount of abbreviation halves of hole carrier concentration which asks for quantity of an atom which acts as a donor, without covering a wide range and compensating most hole carrier concentration. Therefore, utilization of various semiconductor devices, such as an electric field effect type transistor bipolar transistor and a semiconductor laser, became actual.

[0013]According to the invention of Claim 5, since it was limited to formation of a donor level by using VI fellows element O, S, and Se, Te, etc. as an atom which forms a donor level unlike impurities of both sexes, and also since a possibility of replacing a nitrogen sky lattice point was high, control of hole concentration became easy.

[0014]

[Mode for carrying out the invention]Hereafter, a work example of this invention is described. However, a work example described below illustrates a means to materialize technical thought of this invention, and a method of this invention is not specified as work examples, such as a kind of composition and crystal growth conditions of a material crystal, and vapor-phase-epitaxy gas.

[0015]In a nitride semiconductor light emitting element of this invention, section structure of a gallium nitride system compound semiconductor light emitting element of one work example is shown in drawing 1. Although materials, such as sapphire, SiC, $MgAl_2O_4$, GaN, MgO, Si, and ZnO, may be used for the substrate 1, sapphire is usually used. According to the MO-CVD method, ammonia (NH_4) and trimethylgallium (TMG) which are material gas are used by making conveyance gas into hydrogen on this substrate, The GaN buffer layer 2 was grown

up, and also it continues further and grows up continuously as a layer with the n^+ type GaN layer 3, the n type GaAlN layer 4, the n type InGaN layer 5, the p type GaAlN layer 6, the p^+ type GaN layer 7, carrier concentration that was suitable for a light emitting element, respectively, and thickness. In this invention, by a method involved in carrier concentration control of the p type GaAlN layer 6 and the p^+ type GaN layer 7 which is p type conduction layer, in order to form a high concentration p type conduction layer, impurities which work as a donor in addition to impurities which work as an acceptor are collectively added in a growth layer.

[0016]In a gallium nitride system compound semiconductor, since the nitrogen **** steam pressure at the time of crystal growth is high, a nitrogen sky lattice is easy to be formed. The quantity is called about $1x10^{17}/cm^3$-$1x10^{20}/cm^3$, and if it does not add specific impurities, it generally presents n type conduction. In order to reduce the number of generation of this nitrogen sky lattice as much as possible, it is required to control the steam pressure of NH_4 made into the source of nitrogen, and to consider it as **** steam pressure, and this means is usually taken. Although what is necessary is to add the impurities used as an acceptor and just to compensate a donor, in order to change into p type the conducted type of the growth layer which has such character, it combines with H^+ which exists in the circumference, and the atom for acceptors doped in a growth layer from crystal growth atmosphere checks activation of a dopant. If an acceptor (A^+) exists independently electrically, electrostatic energy will be unstable and, as for an acceptor, the compensation effect will show up toward minimization of free energy by displacement or formation of a compound thing. Concentration is prevented from acceptor increasing by this. However, in doping to the p type Ga_{1-z}aluminum$_z$N layer 6 and the P type GaN layer 7 at this invention, To the material gas of TMG, TMA, ammonia, or TMG and ammonia, [as dopant gas] For example, it became easy by supplying Cp_2Mg (cyclopentadienyl magnesium) and SiH_4 (Silang) at about 3:1 rate by flow rate to control the carrier concentration of p type conduction layer to $6x10^{20}/cm^3$. A part of doped Si(s) replace why such an effect was acquired by a nitrogen lattice position, and it forms a shallow acceptor, And most replaced by the III fellows atom position, and formed the shallow donor, and also electrostatic energy becomes stable, in order that Mg similarly replaced by the III fellows element position may serve as a shallow acceptor and this acceptor (Mg^+) and donor (Si^-) may make a pair. It is thought as a result which one Mg which made at least ** the surroundings of this atom pair commits as an acceptor that it is activated to high concentration.

An electrostatic bond was not carried out to an acceptor, but an isolated donor has the operation which neutralizes H^+ under crystal, and had an effect which raises the electric conduction rate of p type electric conduction layer.

[0017][Work example 1] How to manufacture the gallium nitride system compound semiconductor light emitting element of this invention by the usual MOCVD method is described.

[0018]The fully washed sapphire board 1 is installed into a reaction vessel, it heats to 1100 ** by making hydrogen into conveyance gas, and heat cleaning of a sapphire board is performed. Temperature is lowered to 500 ** after this processing, and the 200-A GaN buffer layer 2 is grown up to be conveyance gas in a sapphire substrate face, using TMG (trimethylgallium) and ammonia as hydrogen and material gas. Stop TMG gas after that, raise substrate temperature to 1030 **, and material gas is made into TMG and ammonia, And Silang Guth is used for dopant gas in order to dope Si, and 3.5-micrometer thickness growth of the n+GaN layer of carrier concentration $1x10^{19}/cm^3$ is carried out for negative pole contact.

[0019]Then, in order to reduce the dope of Si, Silang Guth's flow was lowered, 0.5 micrometer of n type GaN layers which made carrier concentration $1x10^{18}/cm^3$ were grown up, and the GaN cladding layer 3 of the two-layer structure was formed. While stopping both material gas and dopant gas after growth of the n type GaN cladding layer 3, lowering substrate temperature to 850 ** and changing conveyance gas to nitrogen, Silang Guth is used for TMG, TMI (bird methyl in JUUMU) and ammonia, and dopant gas for material gas, and the n type $In_{0.15}Ga_{0.85}N$ layer 5 of 100A thickness is grown up. Then, while interrupting material gas and dopant gas and ****(ing) substrate temperature at 1030 **, The material gas TMG and ammonia, and also TMA (bird methyl aluminum), Cp_2Mg (cyclopentadienyl magnesium) and Silang Guth were used at about 3:1 rate as dopant gas, and 0.2 micrometer grew the p type $aluminum_{0.1}Ga_{0.9}N$ layer 6 which doped Mg and Si.

[0020]Carrier concentration of an obtained layer was $1x10^{18}/cm^3$. TMA was stopped after p type AlGaN layer 6 growth, and also flow rate of Cp_2Mg and Silang was made to increase at

same rate, and the p^+ type GaN layer 7 which doped Mg and Si simultaneously was grown up into 0.3-micrometer thickness.

[0021]After p^+ type GaN layer growth, 700 ** and heat treatment for 20 minutes were performed for a growth board taken out from a reaction vessel in a nitrogen atmosphere, and low resistance-ization of p type conduction layer was promoted. Resistivity of obtained p type conduction layer was 0.040-cm, and hole carrier concentration was $8x10^{19}/cm^3$.

[0022]By a method well learned in a growth layer pass the above process, the negative pole was formed in a P^+ type cladding layer to an anode and an n^+ type cladding layer, respectively, and a light emitting diode of a 500-micrometer angle was created.

[0023]When 20 mA of forward direction current was sent, uniform luminescence was obtained on the forward voltage 3.8V, a luminescence output of 1.5 mW, and a luminescence wavelength of 410 nm.

[0024][Work example 2] In growth of the p type AlGaN layer 6 of the work example 1, as a p-type dopant, Cp_2Mg (cyclopentadienyl magnesium) gas, Using hydrogen sulfide (H_2S) as an n type dopant, those flow rate was passed at a rate of 3:1, and the p type $aluminum_{0.1}Ga_{0.9}N$ layer 6 which doped Mg and S was grown up to be 0.2-micrometer thickness. Carrier concentration of an obtained layer was $2x10^{19}/cm^3$. - [interrupting TMA gas and maintaining a rate for Cp_2Mg and H_2S which are dopant gas, after growing up the p type AlGaN layer 6] -- it increased and the p^+ type GaN layer 7 was grown up to be 0.3-micrometer thickness. Carrier concentration of this layer was $5x10^{20}/cm^3$.

[0025]When other processes create a light emitting diode similarly, they are 20 mA of order current, a luminescence output is 1.9 mW and 3.1V and a luminescence wavelength of forward voltage are 410-nm **. - The characteristic was acquired.

[0026]

[Effect of the Invention]With as mentioned above, realization of the high concentration p type conduction layer [according to this invention] in p-n junction of a nitriding thing compound semiconductor, an ohmic electrode, etc., The useful nitride semiconductor element which improved the performances, such as the optical power characteristic of light emitting elements, such as a visible light emitting diode and a visible semiconductor laser, which is mainly concerned with blue, and an electrical property, can be provided.

[Brief Description of the Drawings]

[Drawing 1]It is a sectional view showing **** of the light emitting element concerning concrete 1 work example of this invention.

[Explanations of letters or numerals]1 substrate 2 -- buffer layer 3 n^+ type GaN layer 4 n type AlGaN layer 5 -- n type InGaN layer 6 p type AlGaN layer 7 P^+ type -- GaN layer 8 negative-pole 9 anode

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[Translation done.]